Article title	Comparing process-based wheat growth models in their simulation of yield losses caused by plant diseases
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Abstract	Plant diseases are major causes of crop yield losses globally, yet their effects represent a poorly documented source of uncertainty in crop modelling. Ignoring the effects of plant diseases in crop models may lead to large overestimations of current and future crop production levels. Simulation modelling must be seen as a necessary instrument to understand systems and predict their behaviours. This instrument is therefore necessary when profound changes in system structures are envisioned in view of, e.g., ecological intensification or climate adaptation, which necessarily will change injury profiles by plant pathogens and pests. Here, damage mechanisms associated with four major diseases of wheat (brown and yellow rust, septoria tritici blotch and powdery mildew) are considered. These diseases and their damage mechanisms are featured in WHEATPEST, a process-based model for wheat growth under disease. The same damage mechanisms were thus incorporated into four wheat growth models (HERMES, WOFOST_GT, SSM_WHEAT, DSSAT-Nwheat), which did not account for yield losses to diseases before. A benchmark experimental data set from the Netherlands was used to perform two calibration steps to simulate disease-free attainable wheat yields (Ya), first by using the experimentally measured crop development and yields as reference, and second by further using the observed leaf area dynamics. A simulation experiment was then conducted with the five models, with three independent factors: (i) each of the four wheat diseases (individually or combined), (ii) the shape of disease progress curves, and (iii) the maximum disease severity. We analysed the simulated crop growth, actual crop yield (Y), and absolute (YL = Ya – Y) and relative (RYL = YL/Ya) yield loss, at different levels of these three factors. In a last stage of analysis, we simulated the effects of Ya on YL and RYL. Maximum severity of disease had the strongest effect on simulated Y and on YL, while there were also significant differences among models in the simulated YL. Powdery mildew and brown rust were generally associated with higher and lower YL, respectively. Simulated RYL increased as the Ya was decreased. Increase of RYL at lower Ya was attributed to a larger reduction of intercepted radiation at low green leaf area index. This work outlines the rationale for implementing damage mechanisms associated with plant diseases into crop models, and provides the necessary first step towards scenario analyses where the consequences of technology shifts, climate change, and changes in disease patterns may influence the magnitude of yield losses to plant diseases.
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